Finding Near Earth Objects
Before They Find Us!

Workshop for South Africa

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Near Earth Object
Programs Executive
NASA HQ

March 10, 2014

CHELYABINSK EVENT

February 15, 2013
17-20 meter object
~500-550 kilotons TNT

CHELYABINSK EVENT

February 15, 2013
1613 citizens injured
~$30 million damages

United States Government Policy and Approach Regarding Planetary Defense

NEO Threat Detection

Within US Government:

- NASA will coordinate NEO detection and threat information from all organizations within the NEO observation community
- NASA has instituted communications procedures, including direction with regard to public release of information
- NASA notification procedures are set into motion only after the necessary observations, analyses, and characterization efforts have taken place to determine that a space object indeed represents a credible threat
  - Depends on level of risk and urgency, may unfold for years after detection
  - Will entail various combinations of:
    - Increased monitoring
    - Cross-checks of potentially hazardous trajectories as needed
    - Accelerated observations and orbit determination if potential hazard is near term

NEO Threat Notification

Upon notification from NASA:

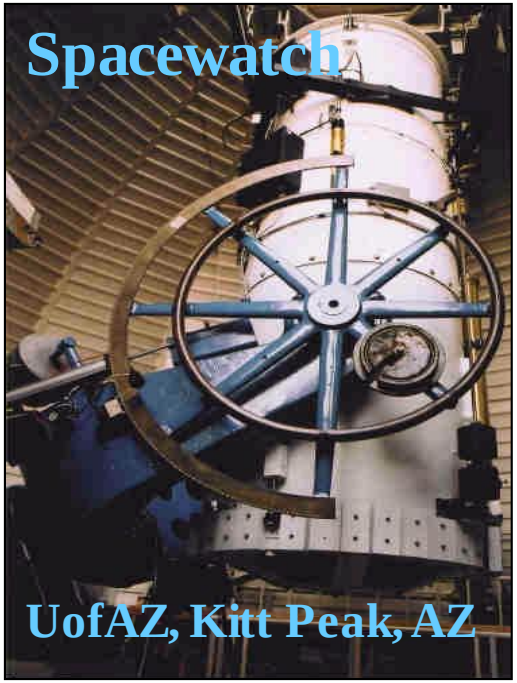
Of impending NEO Threat to United States territory:

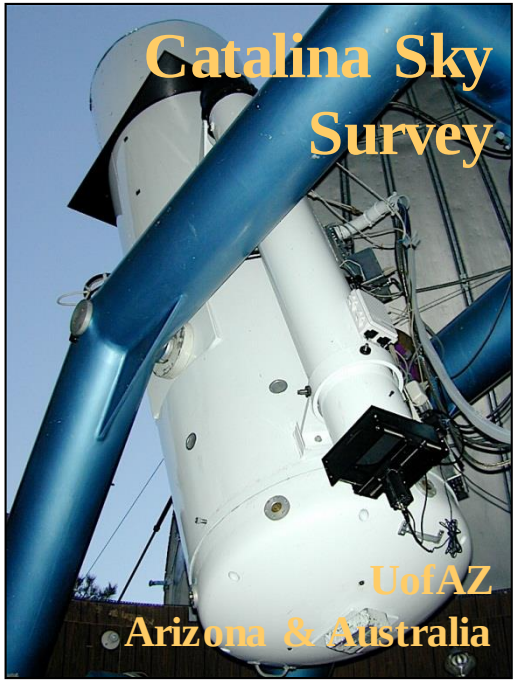
- The Federal Emergency Management Agency (FEMA) takes lead to notify appropriate Federal, state and local authorities and emergency response institutions utilizing existing resources and mechanisms
  - When time/location of affected areas known, activate National Warning System
  - Analogous to large re-entering space debris and/or hurricane warning procedures
  - Post-impact event, analogous to other disaster emergency and relief efforts

Of NEO Threat beyond United States territory:

- US Department of State facilitates international notifications in effort to minimize loss of human life and property
  - Bilaterally through diplomatic channels to potentially affected countries
  - To member nations of multilateral forums – UN entities (OOSA, COPUOS), NATO, etc
  - Post-impact event, convey offers of disaster relief and technical assistance

NASA's NEO Search Projects (circa 2004)





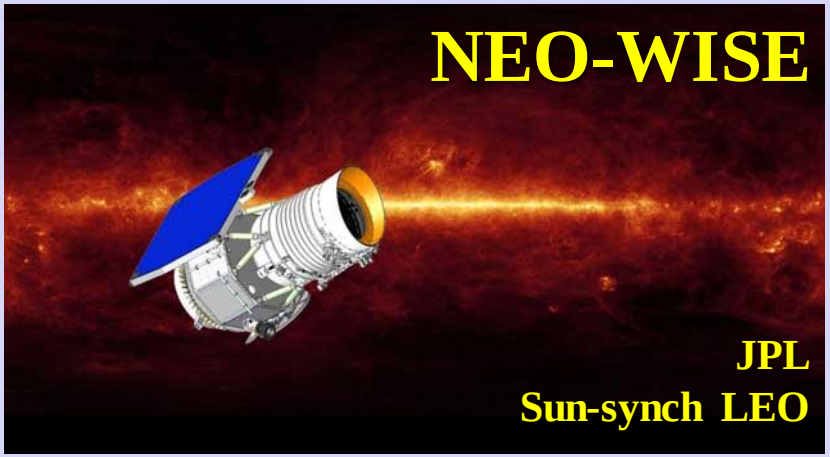
NASA's NEO Search Program
(Current Systems)

Minor Planet Center (MPC)
- IAU sanctioned
- Int'l observation database
- Initial orbit determination

http://minorplanetcenter.net/

NEO Program Office @ JPL
- Program coordination
- Precision orbit determination
- Automated SENTRY

http://neo.jpl.nasa.gov/



Operations
Jan 2010
Feb 2011,
129 NEAs found

Reactivated
Sep 2013

Ops in Dec
6 NEAs 1 comet

Data Analysis/Management

- Minor Planet Center (MPC)
  - Smithsonian Astrophysical Observatory, Cambridge, MA
    - Dr Tim Spahr, Director
  - Widewide observation coordination and correlation, initial orbit determination

  http://minorplanetcenter.net/

- Near Earth Object Program Office
  - Jet Propulsion Laboratory, Pasadena, CA
    - Dr Donald Yeomans, Program Manager
  - Precision orbit determination and hazard prediction
    - Compares results with NEODynamics System, Univ of Pisa, Italy

  http://neo.jpl.nasa.gov

NEO Observations Program

US component to International Spaceguard Survey effort
Has provided 98% of new detections of NEOs since 1998

Began with NASA commitment to House Committee on Science in May 1998 to find at least 90% of 1 km and larger NEOs

- Averaged ~$4M/year Research funding 2002-2010
- That goal reached by end of 2010

NASA Authorization Act of 2005 provided additional direction:

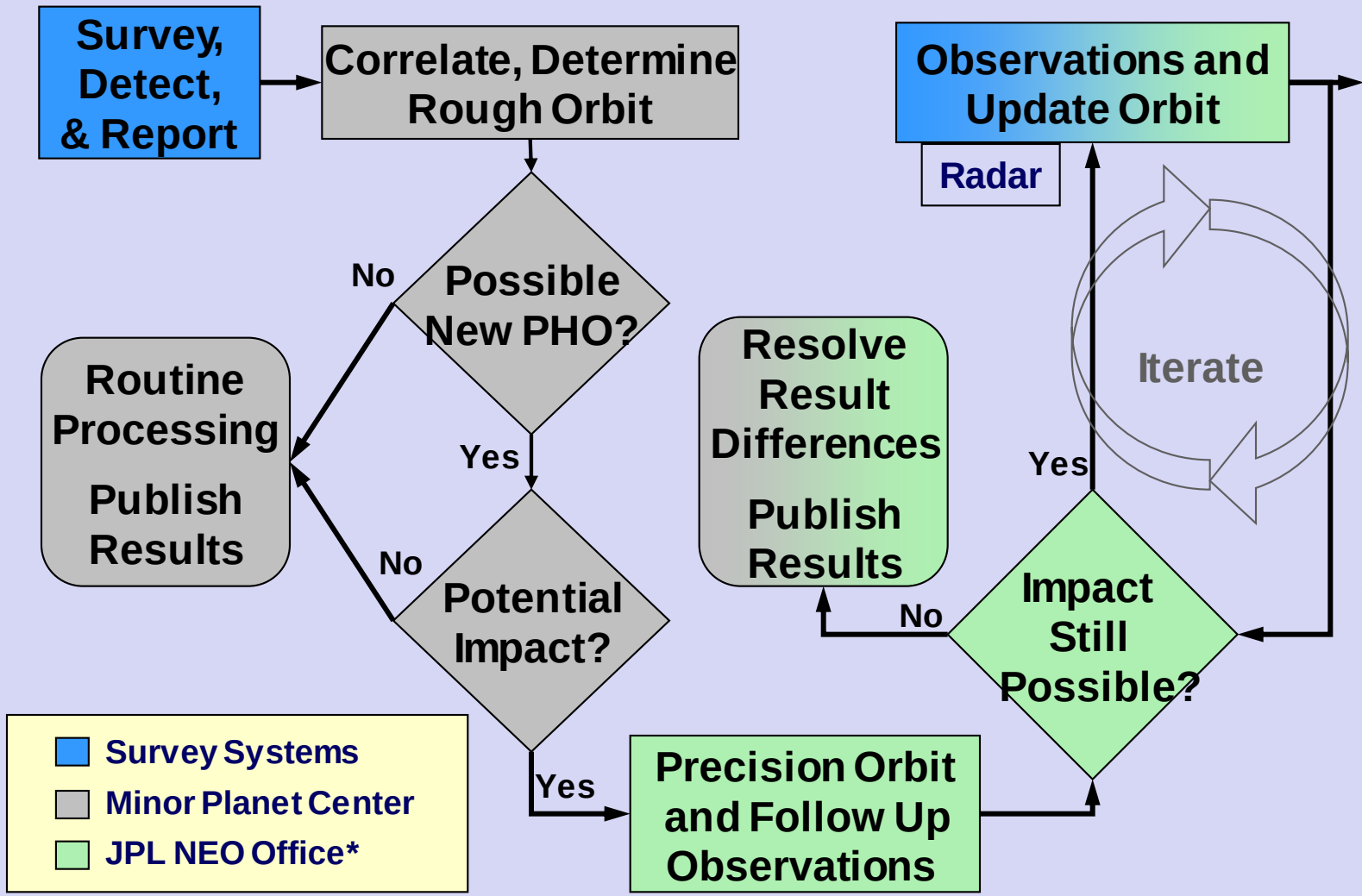
"...plan, develop, and implement a Near-Earth Object Survey program to detect, track, catalogue, and characterize the physical characteristics of near-Earth objects equal to or greater than 140 meters in diameter in order to assess the threat of such near-Earth objects to the Earth. It shall be the goal of the Survey program to achieve 90 percent completion of its near-Earth object catalogue within 15 years [by 2020].

Updated Program Objective: Discover ≥ 90% of NEOs larger than 140 meters in size as soon as possible

- Starting with FY2012, now has $20.5 M/year
- FY2014 budget increases to $40.5 M/year

Spaceguard Survey Catalog Program

Current Spaceguard Survey Infrastructure and Process

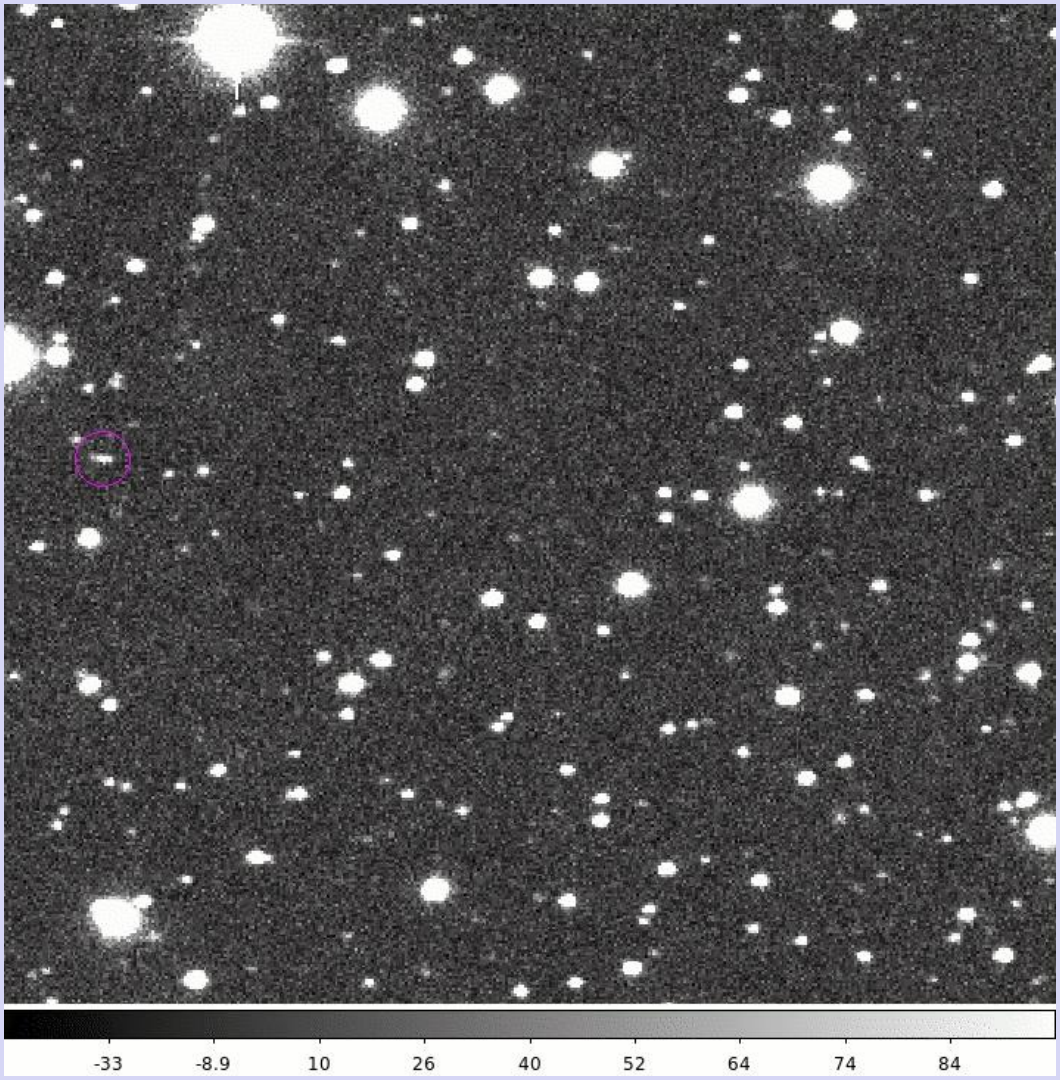


Alerts to NASA HQ

- **MPC** - PHO of interest
- **MPC** - possible close approach
- **JPL** - reports potential for impact
- **JPL** - publishes probability of impact

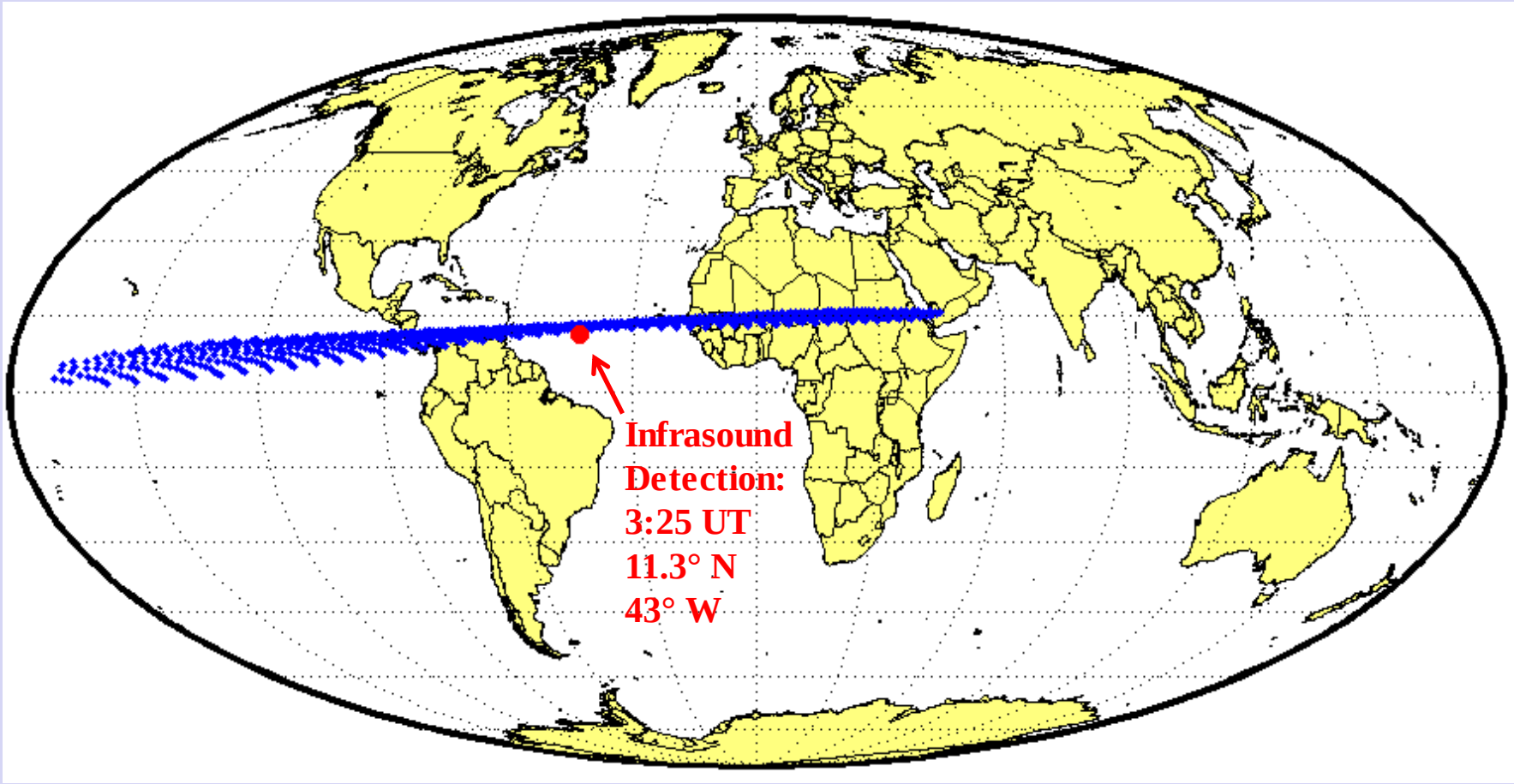
* In parallel with NEODyS

Discovery Images of Asteroid 2014 AA



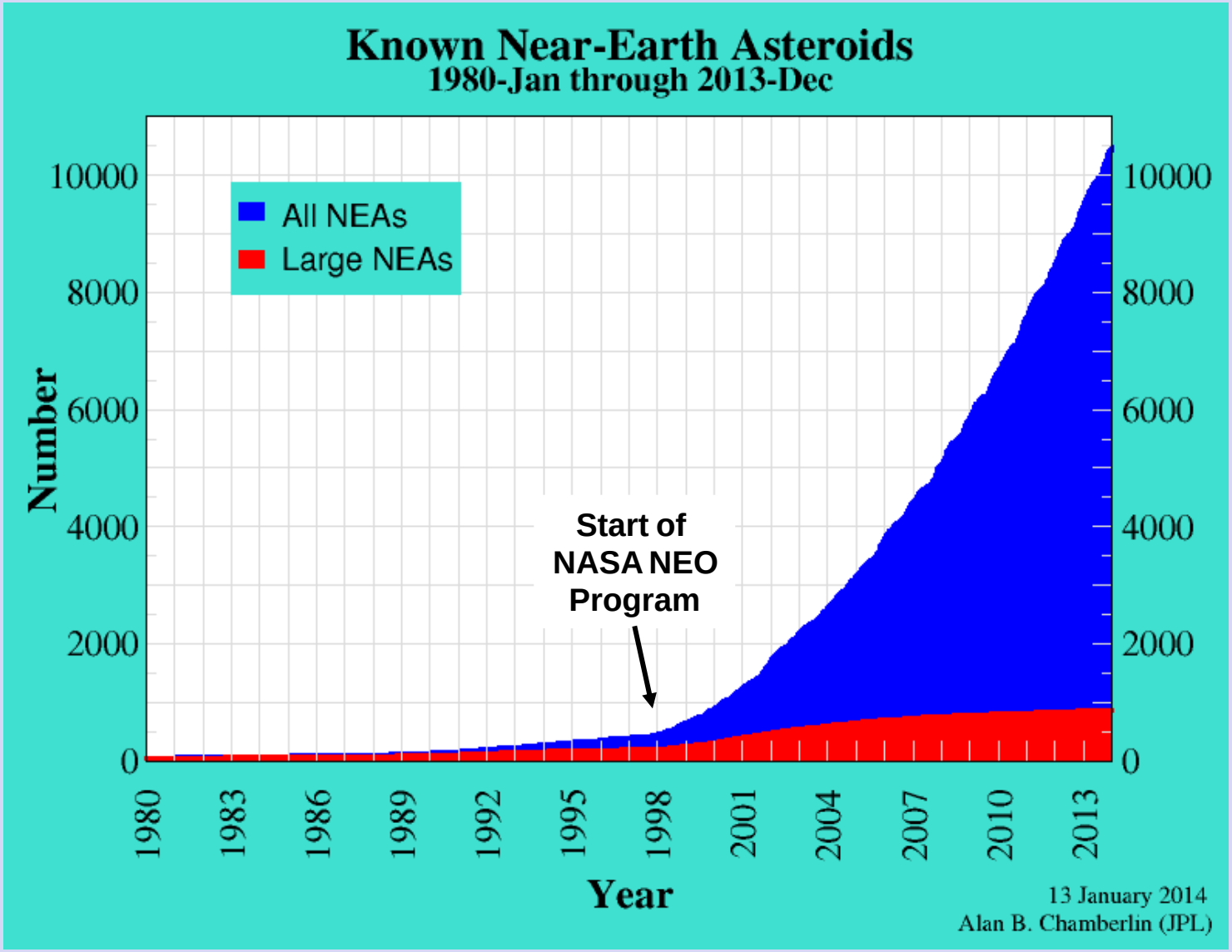
Courtesy of Catalina Sky Survey

2014 AA Predicted Impact Location



Credit Steve Chesley, NEO PO, JPL

Known Near Earth Asteroid Population



10,765
3/1/14

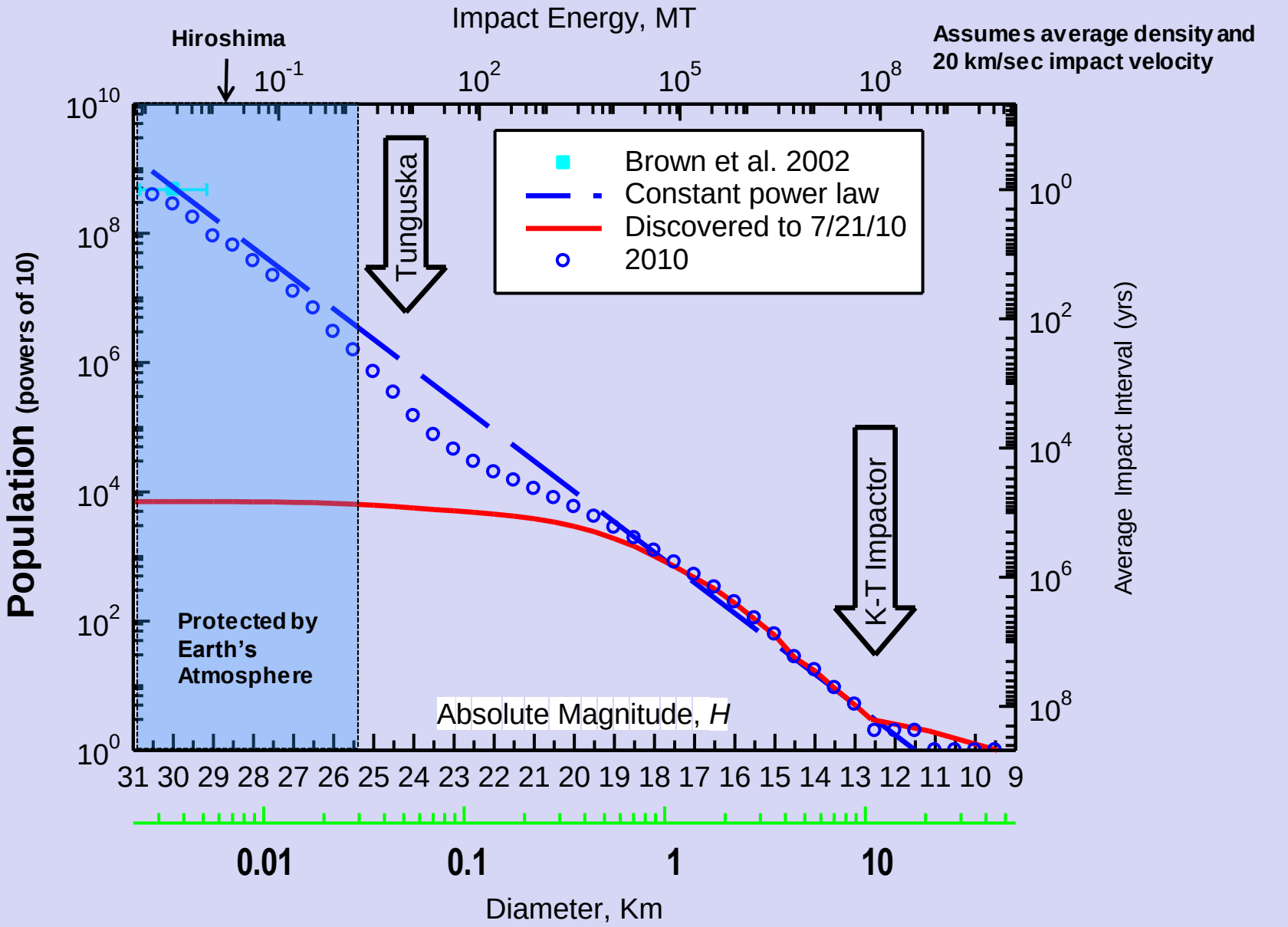
Includes 94 comets

1455 PHAs

866
3/1/14

154 PHAs

Population of NEAs by Size, Brightness, Impact Energy & Frequency (A. L. Harris 2010)



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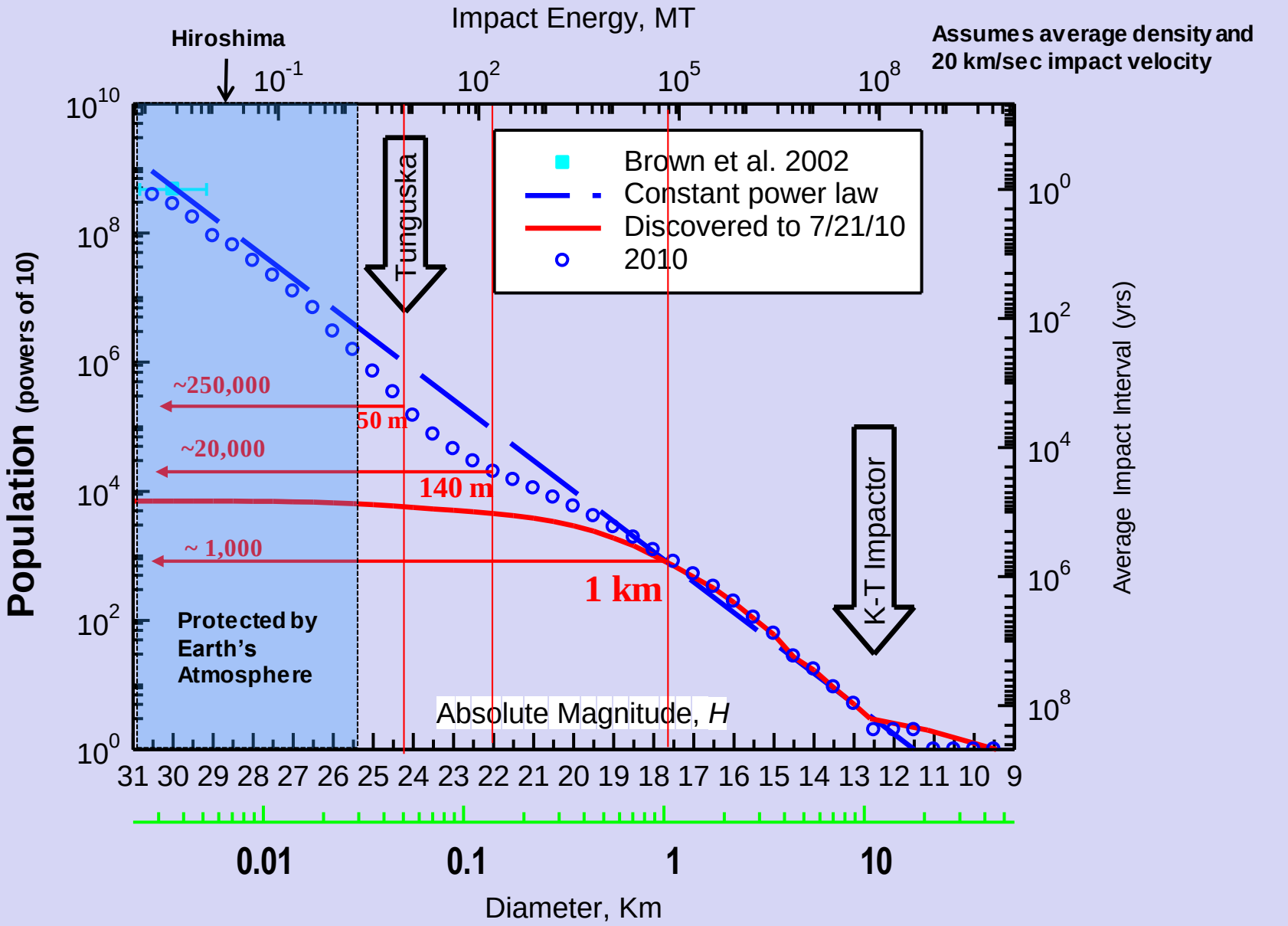

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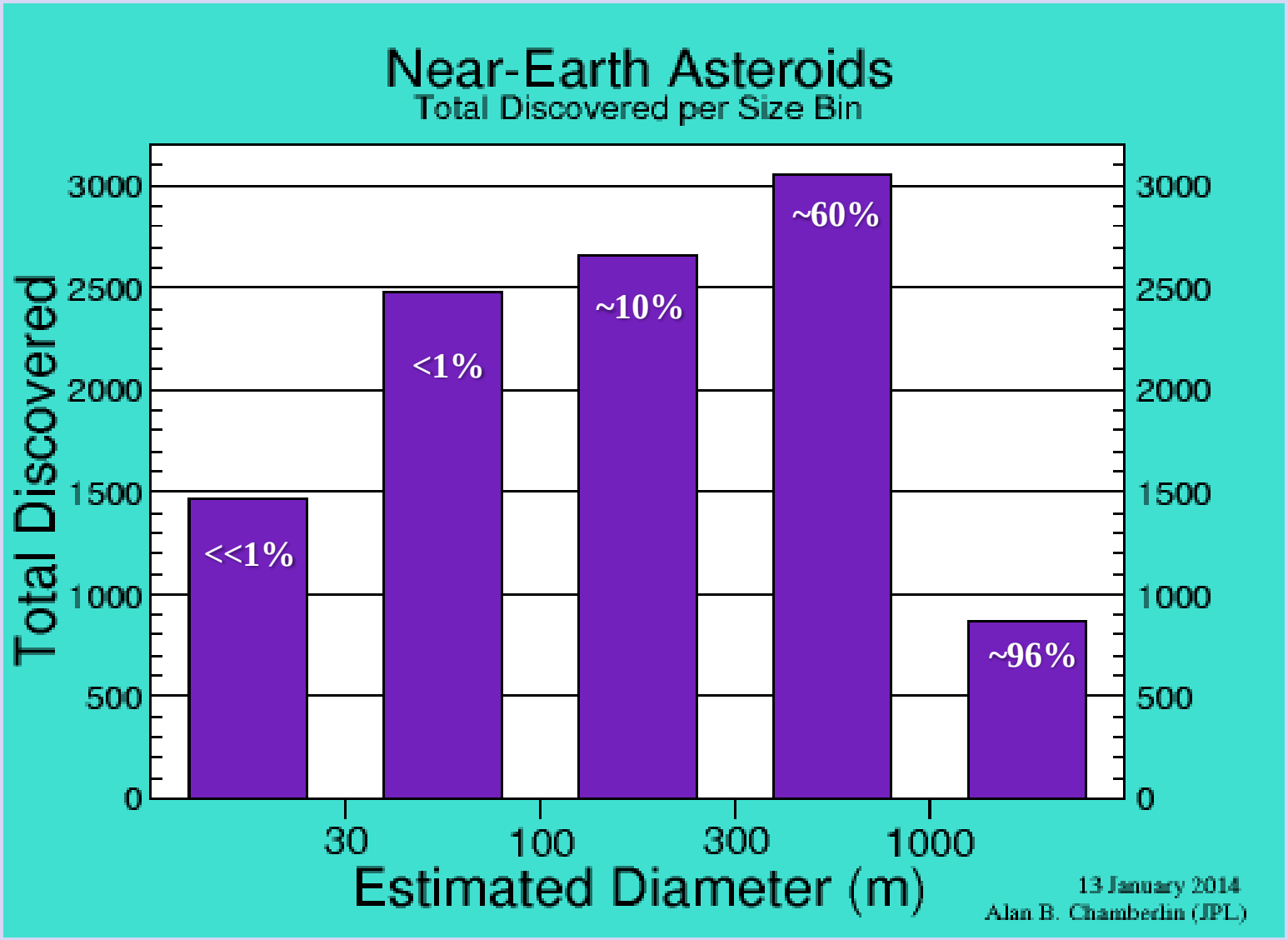


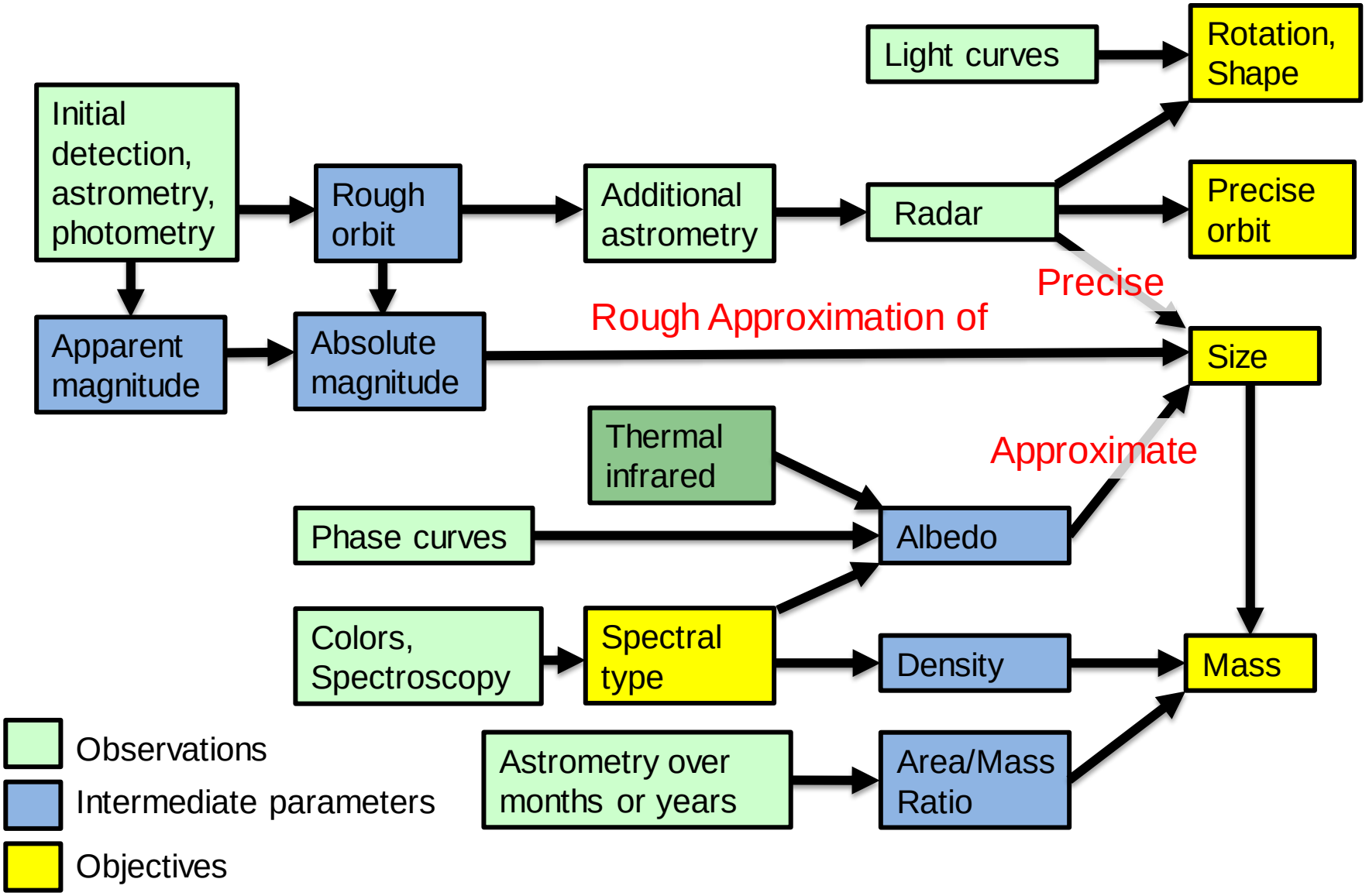
Physical Characterization of NEAs

- **Radar** is essential for obtaining an accurate estimate of size and shape to within ~2 m, as well as rotation state.
- Ground-based and space-based **IR** measurements are important for estimating albedo and spectral class, and from these an approximate density can be inferred.
- **Light curves** are important to estimate shape and rotation state.
- **Long-arc high-precision astrometry** is important for determining the area-to-mass ratio.
- Mass is estimated from size and shape using an inferred or assumed density, and it should be constrained by the estimate of the area-to-mass ratio. Even so, mass may only be known to within a factor of 3 or 4.
- Composition can only be roughly assessed via analogy to spectral class.

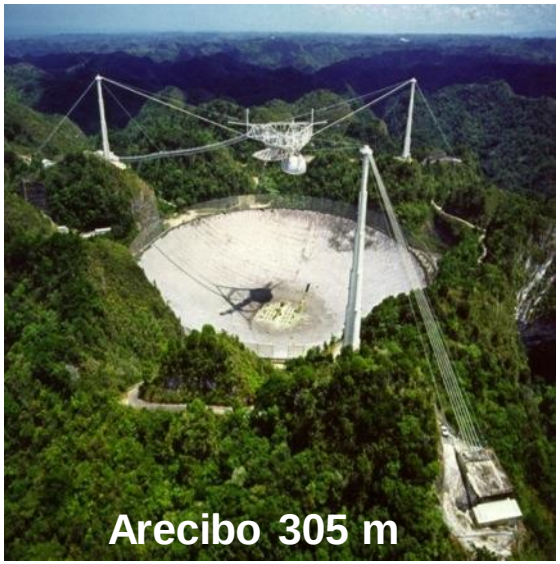
Assumed albedo
ρ = 0.04

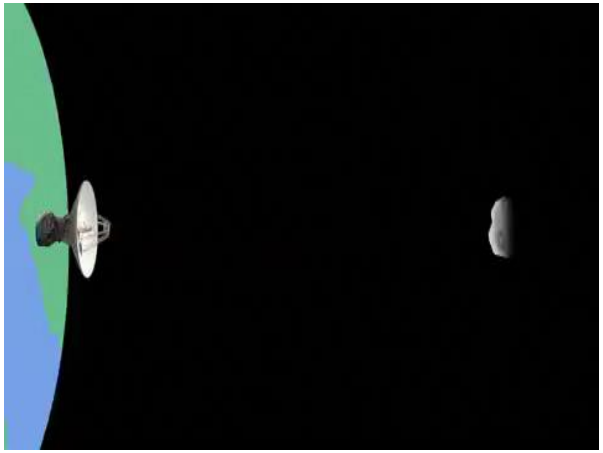
Assumed albedo
ρ = 0.34

Characterization Process



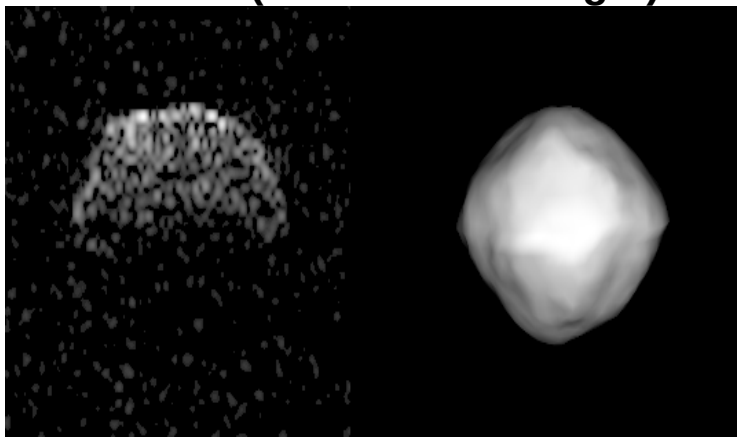
Radar Observations of NEOs





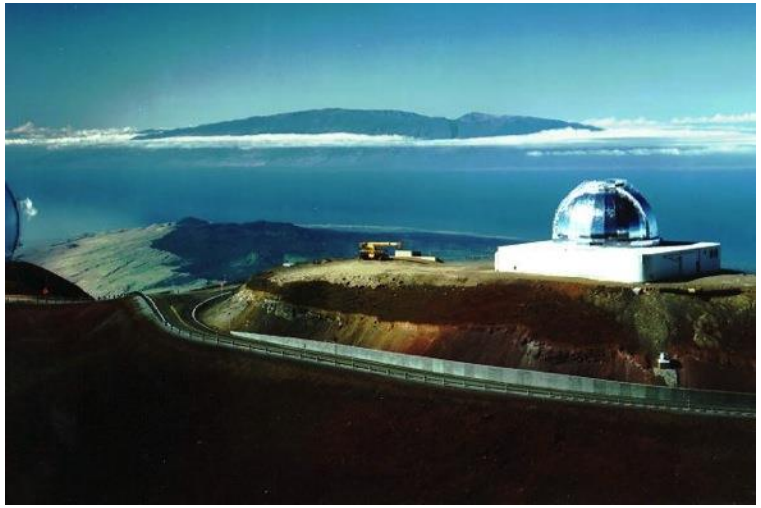
- These are complementary capabilities.
  - Arecibo has more power and range
  - Goldstone has more resolution and field of regard
- Currently, 70-80 NEOs are observed every year.
- Radar observations can provide:
  - Size and shape to within ~2 meters.
  - High precision range/Doppler orbit data.
  - Spin rate, surface density and roughness.

Bennu (OSIRIS-ReX Target):



Observations **Shape Model**

NEO Infrared Characterization



NASA InfraRed Telescope Facility (IRTF)

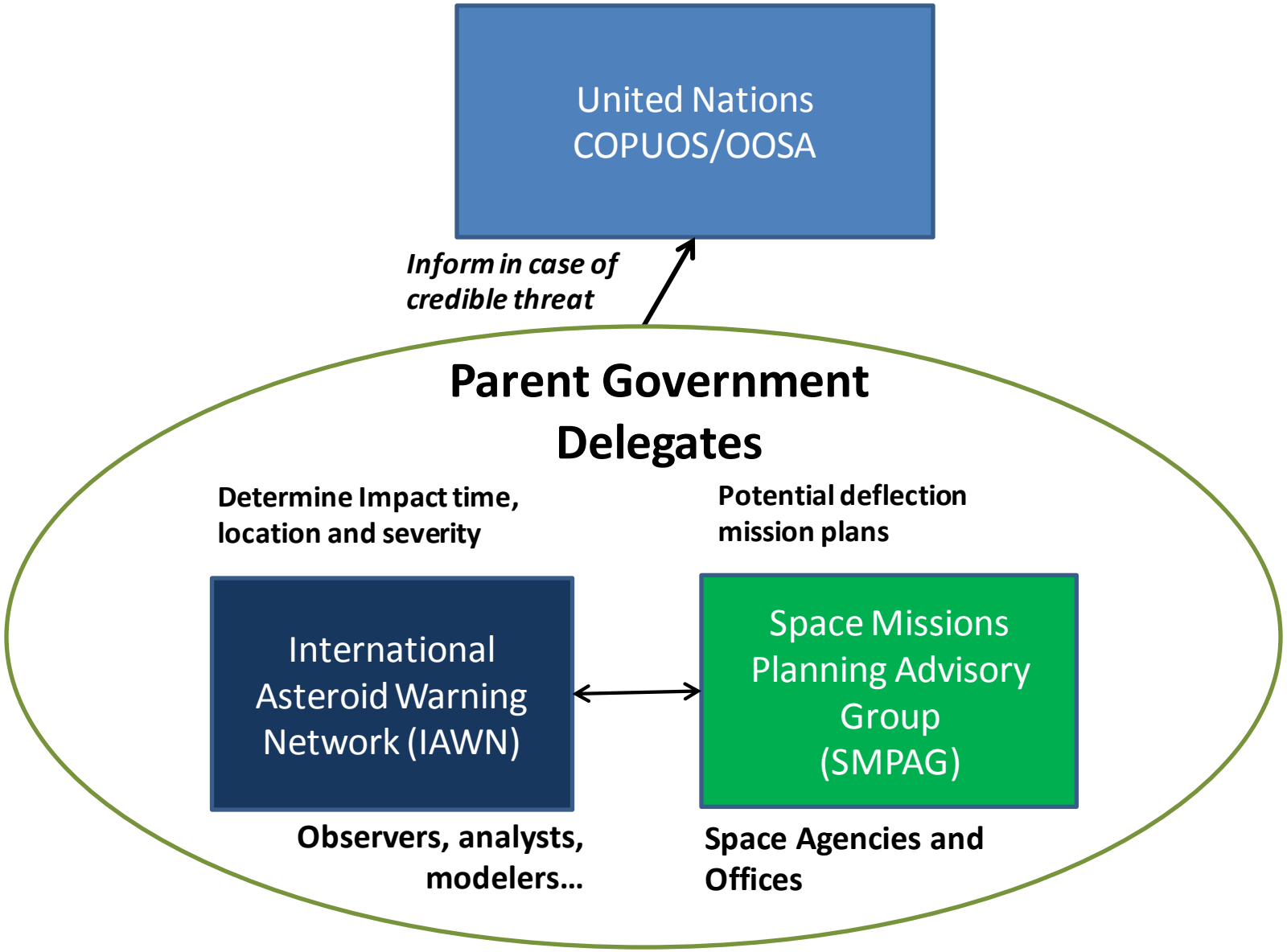
- Dedicated Planetary Science Observatory
- Characterization of Comets and Asteroids
- Spectroscopy and Thermal Signatures
- On-call for Rapid Response on Discoveries

Spitzer Infrared Space Telescope

- Orbit about Sun, ~176 million km from Earth
- In extended Warm-phase mission
- Characterization of Comets and Asteroids
- Thermal Signatures, Albedo/Sizes of NEOs
- Longer time needed for scheduling

UN Office of Outer Space Affairs
Committee on Peaceful Uses of Outer Space

Overview for NEO Threat Response*



*http://www.oosa.unvienna.org/oosa/en/COPUOS/stsc/wgneo/index.html

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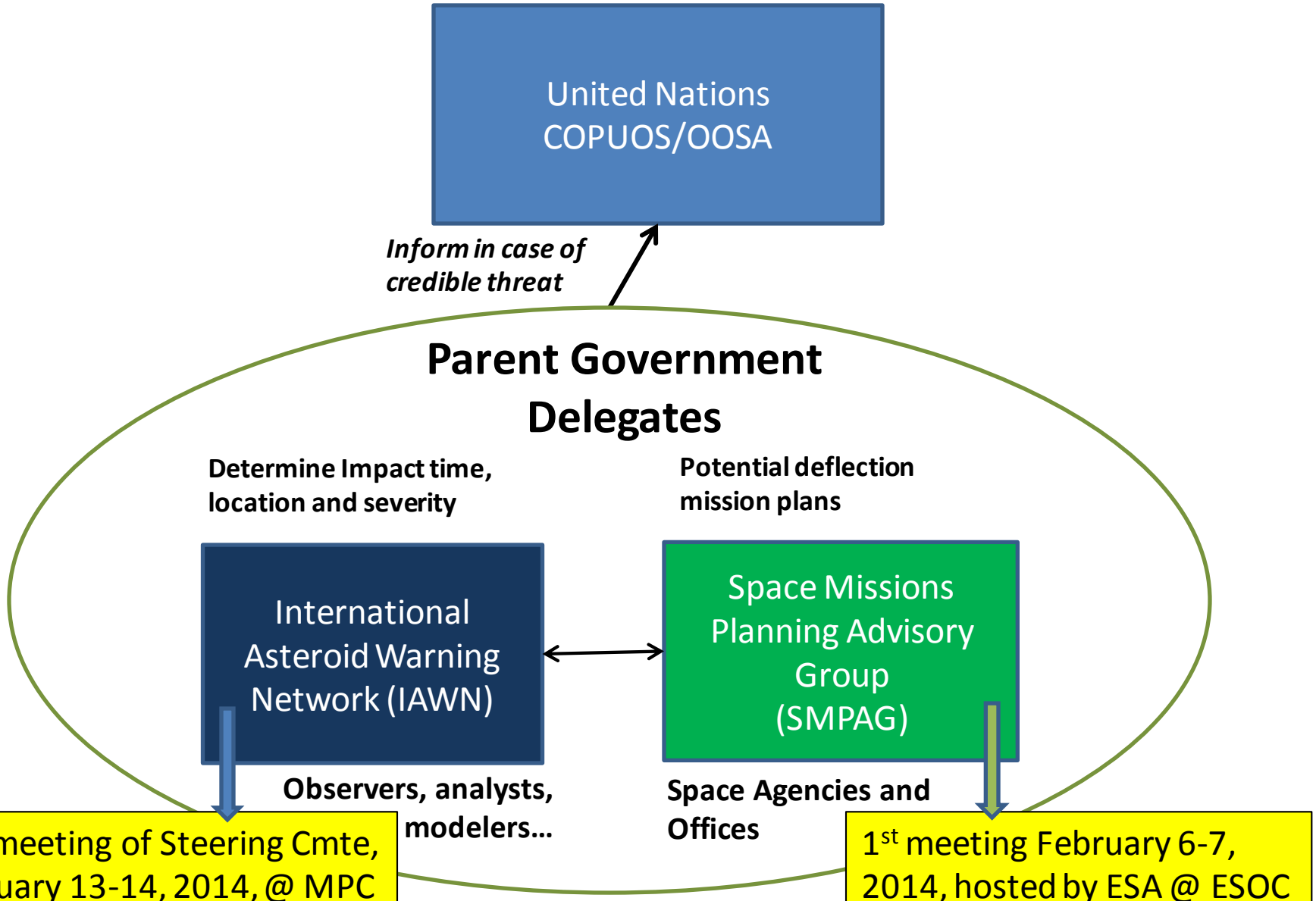
Overview for NEO Threat Response



IAWN Meeting Information

- On 13-14 January 2014, the first meeting of the International Asteroid Warning Network (IAWN) Steering Committee meeting was hosted by the Minor Planet Center (MPC), at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts.
- Presentations were given by many NEO survey and characterization observer teams in the US and other nations
- Discussion was held on IAWN purpose and organization of Steering Committee
- Agenda, presentations, and findings are published at:

  http://minorplanetcenter.net/IAWN

IAWN Participation

IAWN *ad hoc* Steering Committee Members

- Sergio Camacho (UNCOPUOS/NEO AT-14 Chair) - Mexico
- Lindley Johnson (NASA HQ/NEO PE) - United States
- Detlef Koschny (ESA/ESTEC)*
- Boris Shustov (Institute of Astronomy, RAS) - Russia
- Tim Spahr (MPC) - United States
- Giovanni Valsecchi (IAPS/NEODyS) - Italy
- Karel van der Hucht (SRON/IAU)†
- Patrick Michel (Observatoire de la Côte d'Azur/CNRS)* - France
- Don Yeomans (JPL/NASA NEO PO) - United States
- Alan Harris (DLR)* - Germany

Plus 28 other presenters, mostly representatives from US observatory and research teams, but also JAXA and Canadian Space Agency

(* denotes attendance via telecon; † was not able to attend)

IAWN Findings (Slide1of 2)

1) The IAWN Steering Committee recognizes the needs to encourage additional participation in the IAWN and expand recruitment of other nations to the effort. These potential partners include, but not limited to: Russia, Japan, Canada, India, China, United Kingdom, France, and multinational astronomical institutions such as the European Southern Observatory (ESO).
2) A Statement of Intent should be drafted providing guidance for IAWN's operational principles and acknowledges the participation of each partner to the IAWN. It should address the goals:
   a) For the global NEO database and methods within the IAWN
   b) For communicating information to external audiences, including politicians, policy makers, emergency management, and the public

   It should also define basic roles and responsibilities of the Steering Committee.
3) IAWN should seek to enhance NEO discovery and follow-up observations through further international cooperation and coordination, especially in the southern hemisphere. IAWN should encourage use of existing ground-based telescopes for follow-up observations, to bridge gaps in global sky coverage, and to facilitate coordination of existing capabilities for more effective use.

IAWN Findings (Slide 2 of 2)

4) Through further international collaboration, the IAWN should seek to accomplish the following goals and objectives:
   a) establish an international rapid all-sky search capability that is focused on discovering smaller, imminent impactors (e.g., Chelyabinsk event or larger);
   b) develop and operate an effective, space-based NEO infrared survey telescope to significantly accelerate the current NEO discovery rate.
5) The IAWN Steering Committee should organize a two-day workshop on strategies and planning of communication regarding NEO impact hazards. The workshop should focus upon critical assessment of historical and hypothetical messages, strategies, and plans developed by the NEO community in an effort to improve upon international communications concerning potentially hazardous asteroids and impact risks. Social scientists with expertise in public communication, risk communication, cross-cultural communication, risk perception, emergency preparedness and disaster management should be utilized to organize and conduct the workshop.

SMPAG Formulation Meeting

On 6-7 February 2014, the first meeting of the NEO Space Mission Planning and Advisory Group (SMPAG) was hosted by the European Space Agency (ESA), at the European Space Operations Center (ESOC) in Darmstadt, Germany

Delegations attended from:

- AEM (Mexico)
- ASI (Italy)
- CNES (France)
- CSA (Canada)
- Chile
- DLR (Germany)
- ESA
- Ghana
- JAXA (Japan)
- NASA (USA)
- ROSCOSMOS (Russian Federation)
- SSAU (Ukraine)
- UK Space Agency (UK)

Representatives of NEO AT-14 and UN Office for Outer Space Affairs (UNOOSA)

SMPAG Meeting Information

- Brief presentations were given by many national delegates on their activities related to hazardous asteroid mitigation
- Discussion was held on SMPAG Terms of Reference to produce the final text
- ESA was elected by consensus to be the interim chair of the SMPAG
- The second meeting is planned in conjunction with UNCOPUOS in June to focus on technical efforts to date by the members
- Agenda, presentations, and findings adre published on a web page set up by ESA at their NEO Coordination Centre
  - http://cosmos.esa.int/web/smpag